Tropical Cyclone Motion Studies

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Award #: N0001499WR20176

LONG-TERM GOALS

The long-term goal is to improve the prediction of tropical cyclone track and structure so that warnings to the Fleet units afloat and ashore are optimized.

OBJECTIVES

(1) Improve tropical cyclone track prediction within the framework of the Systematic Approach to Tropical Cyclone Track Forecasting (2) Improve understanding of tropical cyclone structure including rapid intensification and extratropical transition.

APPROACH

(1) Utilize the Systematic Approach framework to demonstrate the feasibility of optimizing track forecast guidance. (2) Use the ONR-sponsored Tropical Cyclone Motion (TCM-90) field experiment data set to analyze the environmental factors leading to intensity and structure changes in Supertyphoon Flo. (3) Utilize a new data base of tropical cyclones undergoing extratropical transition in the western North Pacific to document the characteristics and the physical processes involved.

WORK COMPLETED

(1) An analysis of the clusters of five dynamical model tropical cyclone track forecasts has demonstrated the advantages of selective consensus forecasts. (2) An exhaustive study of the TCM-90 data set related to the structure changes of Supertyphoon Flo has been completed with the publication of the Ph.D. dissertation of David Titley (CDR, USN). (3) A Ph.D. dissertation by Peter Klein (LCDR, USN) has utilized numerical model simulations to understand the midlatitude circulation and tropical cyclone contributions in extratropical cyclogenesis.

RESULTS

(1) A conference preprint (Elsberry and Carr 2000) and journal article (Elsberry and Carr 2000) document the advantages to be gained in the Systematic Approach by first rejecting dynamical model track forecasts likely to have a 72-h error greater than 300 n mi, which is called a selective consensus track. Even though only five dynamical models are utilized, each has a different initial analysis and different model physics, so that a type of ensemble forecasting is involved. In addition to the expected result that the consensus mean will have a better performance in the average, the spread about the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2000		**00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Tropical Cyclone Motion Studies	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Meteorology,Naval Postgraduate School,,589 Dyer Rd. Room 254,,Monterey,,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

consensus mean also contains information about the accuracy of the mean track. By first rejecting an erroneous track to form the selective consensus, the errors are reduced relative to the non-selective consensus track from an average of all five tracks. The basis for detecting likely erroneous tracks is described in the Lester Carr report in this volume, which also describes a beta test and preliminary operational tests that demonstrate the viability of real-time track error detection.

A rationale for statistically adjusting the European Centre for Medium-range Weather Forecasts (ECMWF) tropical cyclone track forecasts has been developed (Boothe and Elsberry 2000). These track forecasts are time delayed by about 18 hours and often have large initial position errors because no synthetic tropical cyclone observations are used by ECMWF. An analogous statistical post-processing technique as in Elsberry et al. (1999) will adjust for these deficiencies in the ECMWF track forecasts.

(2) Titley (1998) developed a Multi-Qaudric (MQ) analysis and compared it with the TCM-90 four-dimensional data assimilation (4DDA) analyses of the evolution of Typhoons Flo and Ed. The MQ analysis is shown to provide an alternate, plausible depiction of the tropical atmosphere. These analyses are then used to analyze the physical processes leading to rapid intensification of Flo, but not of Ed. Significant results (Titley and Elsberry 2000) include: (i) existence of a "cyclonic wind burst" extending beyond 1000 km radius at 200 mb during a pre-conditioning period prior to the rapid intensification of Flo; (ii) Flo had developed a warmer core near the tropopause, and was less stable than Ed in the lower- and mid-troposphere prior to the beginning of rapid intensification; (iii) a strong sustained eddy flux convergence (EFC) in the upper troposphere during the pre-conditioning period had the role of a catalyst, since the EFC forcing was significantly reduced during the rapid intensification; (iv) vertical wind shear was not an inhibiting factor in the intensification, rather it appeared to decrease as a result of the rapid intensification; (v) Supertyphoon Flo rapidly decreased in intensity while over warm water and while large EFC forcing aloft was still present, presumably because the interaction with the midlatitude circulation also produced a mid-tropospheric EFC that led to an outward secondary circulation that tends to spin down the mid-tropospheric vortex.

(3) Advances in understanding the extratropical transition of a tropical cyclone to an extratropical cyclone are summarized in the Ph.D. dissertation by LCDR Klein (2000). The conceptual model that Klein developed of the first transformation stage has been published (Klein et al. 2000). Ritchie and Elsberry (2000 a, b) have demonstrated that COAMPS model simulations can reproduce almost all aspects of the cloud evolution during the three transformation steps as Klein found from satellite observations. Those simulations demonstrate the leading role of decreasing sea-surface temperatures during the first step in transformation, and then the increasing effects of vertical wind shear during the second and third steps. The dynamical and thermodynamic processes that determine the structure of the tropical cyclone remnants at the end of transformation are documented based on these high-resolution COAMPS simulations.

Other advances in our studies of the extratropical transition are summarized in the reports of Patrick Harr and Elizabeth Ritchie in this volume.

(4) As an Associate Lead Scientist for Hurricane Landfall (HL) in the U. S. Weather Research Program (USWRP), an opportunity exists to integrate and influence the Navy, NOAA, NSF, and NASA research. An implementation plan for the HL component of the USWRP has been written (Elsberry 2000) and also circulated via the website and several conference venues. Preparation of a position paper and participation as a panel member in a forum sponsored by the Weather Channel and

the American Meteorological Society entitled "Policy Issues in Hurricane Preparedness and Response" led to key recommendations for future support of the USWRP HL component.

(5) I serve as co-chair of the Symposium on Precipitation Extremes for the American Meteorological Society National Meeting in January 2001. A major component of that Symposium will be devoted to tropical cyclone-related precipitation (Gall and Elsberry 2000). In addition to organizing that portion of the Symposium, I will serve on the panel discussion summarizing the status, and colleague Patrick Harr and I will provide the overview of the precipitation aspects of extratropical transition.

(6) I served on the organizing committee for the World Meteorological Organization Third Comparison of Mesoscale Prediction and Research Experiment (COMPARE) that utilized the ONR Tropical Cyclone Motion (TCM-90) data set. A summary of the COMPARE results has been submitted for publication (Nagata et al. 2000).

TRANSITION

The feasibility of the statistical-synoptic track prediction technique will be tested as part of a 6.4 project funded by SPAWAR and offered to JTWC for operational testing. A version for the Advanced Tropical Cyclone Forecast (ATCF) workstation will be tested as part of the SPAWAR project and provided to JTWC, Pearl Harbor, and Norfolk centers.

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